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Sanitary Pipeline Pilot Project After 42-Years of Service in Lima Ohio

Jeff Boschert, P.E., Brian Browne, P.E, CPESC.,
Kent Carlson, and Steven Kayatin, P.E.

ABSTRACT

The Vernon Heights Polyvinyl Chloride (PVC) gravity sanitary sewer was constructed in 1976 for Allen County, Lima, Ohio. This installation was a trial of PVC (SDR 35) as a new material in the system. Fourteen sanitary sewer lines of eight-inch pipe were installed using the material. As a trial, these flexible pipes have been inspected and documented four times over their forty-two years of service.

This paper outlines the results of those inspections, including the most recent inspection conducted in 2018. The 2018 inspection used laser profiling equipment that was not readily available for the previous inspections. The deflections in this trial installation have increased from less than five percent in 1976, at the time of acceptance testing, to as much as thirty-two percent in 2018, after forty-two years of service. The inspections in 1976, 1982, 1989 and 2018 clearly show continuing deflection of the flexible pipes over time.

INTRODUCTION

In 1976 PVC was introduced to the Vernon Heights area of Allen County in Lima, Ohio. PVC (SDR 35) sanitary sewer lines were installed in a small segment of the community as a trial of a material that was new to their system. This subdivision required 3,500 linear feet of eight-inch pipe in 14 manhole-to-manhole sections.

The pipe was installed in the summer of 1976 by a local contractor. Allen County's Manager of Construction paid special attention to all installation practices to ensure a full and fair test. Throughout the alignment, pipeline cover depths ranged from 8- to 13-feet with stable native soil in the pipe zone.

As a test-area, the lines installed in 1976 have been monitored more frequently than would be required in many systems. This monitoring over time provides a strong indicator for establishing a realistic expectation of long-term performance of the flexible pipelines.

The original acceptance testing was conducted eight months after installation and before the lines were placed into service. The go/no-go test indicated that all fourteen PVC lines passed a 5% mandrel test using a 7.5-inch, rigid, 9-leg mandrel (See Figure 1). Six years later, in July of 1982, all of the lines were retested using 5% (7.5-inch), 6.5% (7.38-inch) and 8.5% (7.22-inch) mandrels. Another seven years later (after 13 years of service), in August of 1989, another mandrel test of all fourteen lines was performed.

The testing of these lines in 1976, 1982 and 1989 was limited by the labor-intensive nature of profiling a pipeline using a mandrel at the end of the last century. These tests allowed the operators to identify locations of obstructions. When the operators were unable to pull the mandrel through, the guide ropes were marked to indicate the location of the problem along the alignment and the mandrel was removed. The sections of pipe that were beyond the points of failure in each direction were not tested.

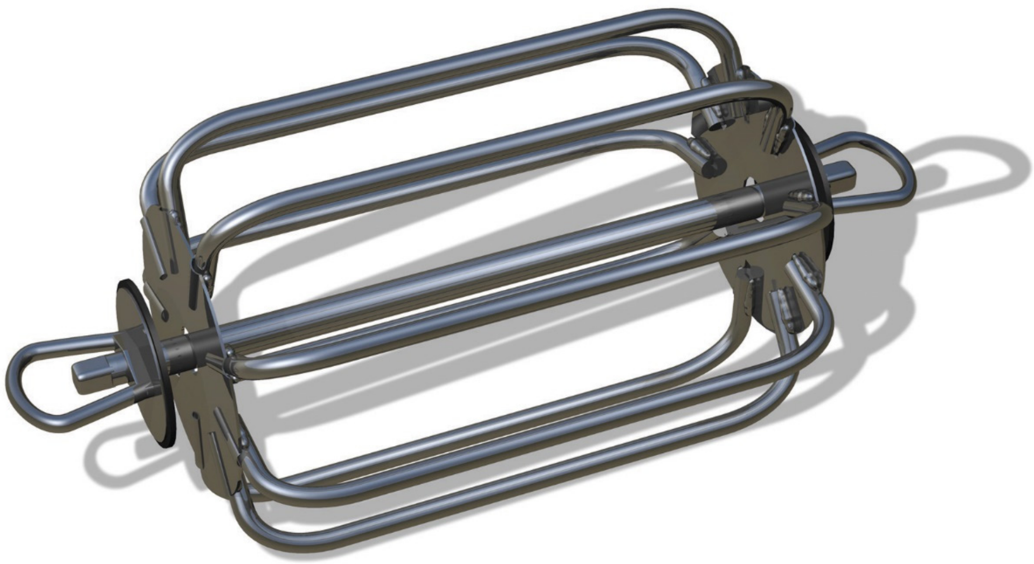


Figure 1: Rigid, nonadjustable, go/no-go 9-leg mandrel used in deflection testing.

The process was long, tedious and often resulted in digging up pipes for small or sometimes non-existent problems. Operators did not know, with any certainty, whether the cause of the stoppage was deflection, offset joints, alignment, cracks in the pipe, a protruding lateral, debris, build up or simply human error.

Since 1989, laser profiling and CCTV (Closed Circuit Television) have become the standard in sewer pipe inspections. The May 2018 inspection provided a much better picture of

Figure 2: A CCTV image from the location of a single point scan in the Lima Study

the condition of all of the pipe. CCTV images were captured in the initial run of the pipe (see Figure 2) and the same pipe was laser-profiled on the return trip.

The availability of specialized cameras and lasers make a more accurate, less physically-demanding and more efficient method of measurement practical. Laser pipe profiling is the use of lasers with camera equipment to accurately measure pipe deflection, cracks and joints coupled with the ability to perform a visual inspection without the need to physically enter the space or dig up a pipe.

Pipe conditions can be thoroughly evaluated before projects are completed, as part of acceptance testing or on existing, in-service pipes. Some states require inspection using these methods for new flexible pipe installations under roadways before the roads are opened to avoid future issues that can be costly.

DESIGN & CONSTRUCTION

The stable native soils in the Vernon Heights area of Ohio provided ideal conditions for this trial. The construction plan was designed using the best practices of the period and the installation was closely monitored to ensure the test provided valid data. While the standards have evolved over the years, the methods used are consistent with the currently accepted best practices for design and installation of flexible pipe as defined by ASTM D2321 *Standard Practice for Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications*.

This project had cover depths of 8- to 13-feet and trench widths of I.D. plus 12-inches on either side of the pipe. The pipeline was bedded with compacted #67 crushed stone (Class I material per ASTM D2321) on both sides and 12-inches over the top of the pipe as required by the county's General Specifications (see Figure 3).

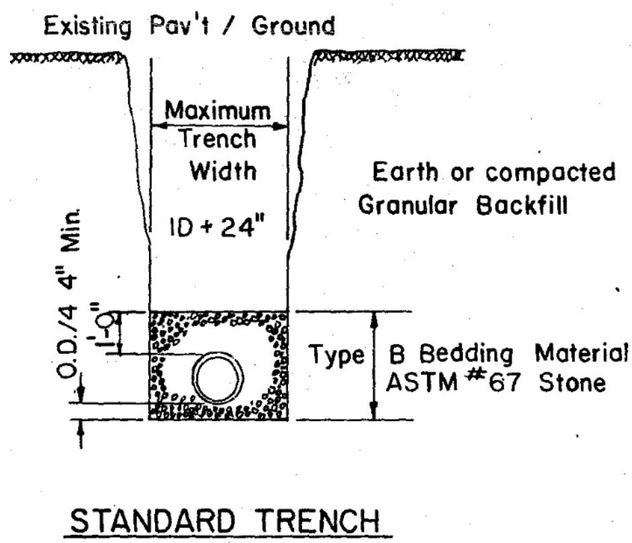


Figure 3: Typical sewer trench from Appendix B of Allen County's General Specifications, 1976

ACCEPTANCE TESTING (1976)

Post-construction acceptance testing was conducted eight months after installation, just prior to the lines going into service. At that time, all 14 sections of the line passed a 5% mandrel test using rigid, nonadjustable, go/no-go 9-leg deflection mandrel gages.

The goal for the acceptance test was to confirm that all of the pipe installed was deflected by less than 5% of the Average I.D. for an eight-inch SDR 35 PVC pipe, or roughly 7.9 inches (as defined in the standard of that period in ASTM D3034 *Standard Specification for Type PSM Poly (Vinyl Chloride) (PVC) Sewer Pipe and Fittings)*. This resulted in a mandrel size of 7.5 inches.

Average I.D. 5% Deflection = (0.95) (7.9 inches) = 7.505 inches

PROGRESS EVALUATION (1982)

In July of 1982, six years after the installation and acceptance testing of these lines, Allen County (Hollinger, H. 1982) repeated the 5% mandrel test and added 6½% and 8½% mandrels for lines that didn't pass the larger mandrels.

Only one of the 14 lines passed the 5% mandrel. Deflection exceeded 5% in the remaining thirteen lines, with three of those lines showing deflection of greater than 6.5% and less than 8.5%. None were found with deflections exceeding 8.5%.

In the 1981 ASTM D3034 standard revision, the concept of Base I.D. dimensions was introduced along with 7.5% mandrel dimensions based upon this new Base I.D. value. Since the 1976 installation and acceptance testing used Average I.D. as the starting point for mandrel sizing, the same standard was employed for both the 1982 and 1989 inspections. Thus, the use of Average I.D. provided a consistent baseline for sizing the mandrel and measuring deflection throughout this study.

Average I.D. is the actual measured I.D. of the pipe. Had the ASTM D3034 Base I.D. (7.665 inches for an eight-inch pipe) been applied, the resulting mandrel would have been almost a ¼-inch smaller.

Base I.D. 5% Deflection = (0.95) (7.665 inches) = 7.282 inches

The GREENBOOK Standard Specifications for Public Works Construction, as well as other municipal standards require mandrel sizing to be based on the actual measured I.D. of the pipe, or the ASTM D3034 Average I.D. and not the ASTM D3034 Base I.D. Table 1 is provided as an illustration of the difference between Average I.D. and Base I.D.

Table 1: Deflection mandrel sizing

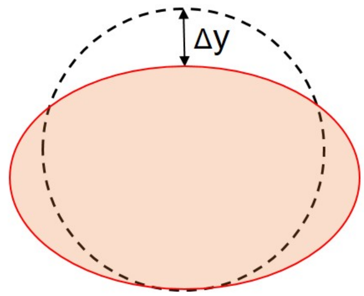
Comparing Average ID to Base ID For an 8" SDR-35 PVC Pipe		
	Average I.D. 7.891* inches	**Base I.D. 7.665* inches**
5% Deflection	7.496	7.282
6.5% Deflection	7.378	7.167
7.5%* Deflection	7.299	7.090*
8.5% Deflection	7.220	7.013
10% Deflection	7.102	6.899
* These values from ASTM D3034		

While a 7.5% mandrel test was not used for any of these inspections, it is included in Table 1 as it is the "maximum deflection test limit for PVC sewer pipe" as defined in ASTM D3034. A 10% mandrel, also not used, is included here as a comparison. A 10% deflection calculated using the Average I.D. is roughly equivalent to a 7.5% deflection calculated using the Base I.D.

DEFLECTIONS AND DEFORMATIONS

The two most commonly anticipated forms of deflection are "ovaling" and "racking."

Ovaling is the bulging out along the springline with a corresponding reduction in height along the vertical axis. This is illustrated in Figure 4.



$$\% \text{ Deflection } = \frac{\Delta y}{\text{Original Dia}} \text{x}\,100$$

Figure 4: Ovaling deflection illustration courtesy of American Concrete Pipe Association (ACPA)

Racking or diagonal deflection is a deflection which does not occur in the vertical and horizontal dimension, but as a shifting of the pipe alignment at a specific point in the line as shown in Figure 5.

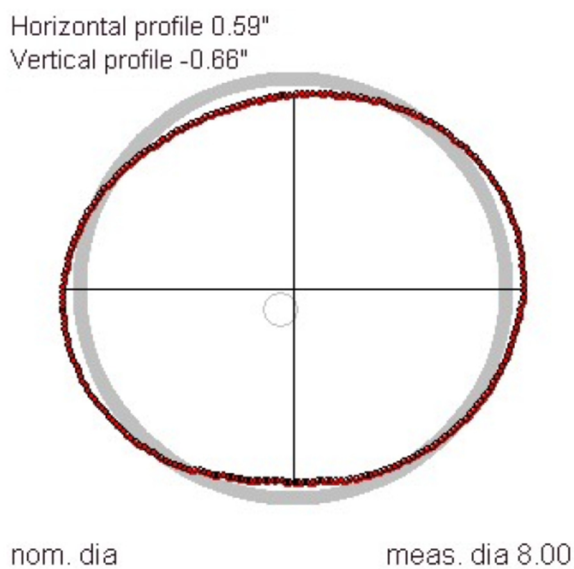


Figure 5: A point scan showing racking of the line.

FOLLOW-UP EVALUATION (1989)

Seven years later (after 13 years of service), in August of 1989, another deflection mandrel test of all fourteen lines was performed to allow for evaluation of the continuing deflection and the rate at which that deflection was occurring. Mandrel gages, based on ASTM D3034 Average I.D. at 5%, 6.5% and 8.5% deflection, were used. None of the fourteen lines would allow a 5%

or a 6.5% mandrel to pass. Only four lines allowed the 8.5% mandrel to pass, indicating that deflection of these four lines was somewhere between 6.5% and 8.5%. The remaining 10 lines had at least one point of deflection greater than 8.5% not allowing passage of the 7.22-inch mandrel.

In 1989, after 13-years of service, 70% of the lines had at least one point of deflection that was beyond 8.5%. The remaining 30% of lines in this test were deflected between 6.5 and 8.5%.

Results of this testing were reported publicly in 1989 in National Clay Pipe Institute's Sewer Sense #25.

LASER PROFILING & CCTV INSPECTION

While the mandrel tests (the standard of the 20th century) were informative and allowed for some evaluation of the rate of deflection, they didn't provide nearly the detail or clarity that is available today from CCTV and laser profiling inspections.

There are currently two types of laser pipe profiling: laser light ring and direct measurement.

Laser light ring requires measurement of the actual diameter of the pipe by hand prior to laser profiling. A separate device is attached to the front of the CCTV tractor which then projects a laser ring, based on those measurement on the inside of the pipe. As the tractor and laser are pulled back thru the pipe, the camera records the laser picture and software converts the image into 2D and 3D reports showing deflection of the pipe.

With direct measurement, the camera and laser measure the pipe circumference using triangulation. The lasers are an integral part of the camera mounted on each side of the camera face, so no additional equipment is required. Two types of measurement can be performed using this equipment: a single-scan, performed with the tractor stationary in the pipe or a line-scan, performed on the entire run of pipe from manhole to manhole.

The single-scan takes 300 measurements as the camera head rotates perpendicular to the wall of the pipe (Figure 5 above is a single scan). Typically, single scans are performed to determine the actual inside diameter of a pipe. This diameter is then used to determine the percentage of deflection for the line scan. The single scan measurements are usually done twice in each run at a section of pipe that appears to be as truly round as possible. These are then averaged and used as the actual (target) diameter of the pipe for the line scan.

The line scan is performed after the regular CCTV inspection. Once the tractor reaches the end of a run, the operator sets the equipment into laser profiling mode. This turns the camera head perpendicular to the wall of the pipe, turns the lasers on and starts the camera head rotating constantly, projecting the lasers onto the wall of the pipe and taking measurements either 20 or 30 times per rotation. The operator retrieves the tractor at a rate of between 5 and 10 feet per minute, while the camera and software record the measurements and build the data set to generate the final reports.

The software creates a 2D graph (Figure 6), showing the range of deflection of the entire run in the horizontal and vertical axes, and a 3D view of the entire run (Figure 7). These graphs show any deflection, the average pipe diameter, and the inclination slope of the line. These are immediately available to the operator/inspector. The scans can then be reviewed on-site to determine if it is necessary to re-enter the pipe and perform single scan measurements at areas of particular concern.

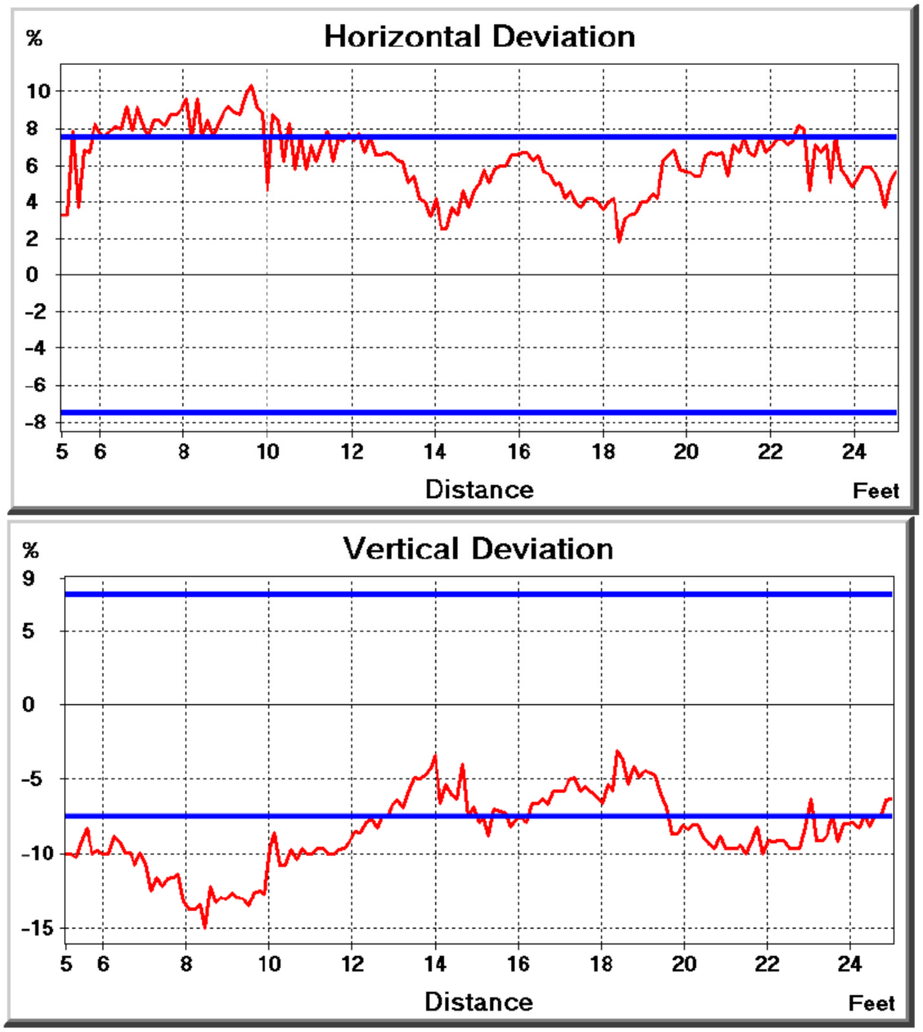


Figure 6: The line scan of 25 feet of pipe in the Lima Study (manhole 19 to manhole 12).

The direct measurement system was used for this inspection because it ensures greater integrity of results, as there is no place for user setup, no ability for the operator to adjust the data received and a reduced opportunity for human error.

In the Figure 7, sample 3D view, the areas in red exceed the maximum allowable deflection of 7.5%. The areas in yellow have exceeded 4% deflection, but are not yet beyond the maximum.

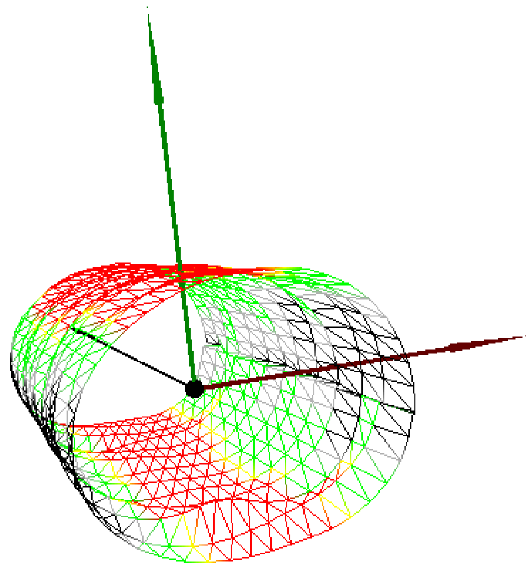


Figure 7: Sample of a spinning laser scan from the Lima study inspection run from manhole 17 to manhole 16.

INSPECTION RESULTS 2018

In 2018, the lines in the Vernon Heights project were inspected again using CCTV and laser profiling. A few runs included isolated areas of severe sag, alignment and deflection issues. Laser profiling was not possible in these areas because the camera could not pass. Results reported in Table 2 only include sections where laser profiling was possible.

While the earlier mandrel test results provide some gage as to the condition of pipe, they do not provide a complete illustration to the extent of the issues. In the 2018 test, all 14 lines would have failed an 8.5% mandrel test (see Table 2), many of them at several different points along the pipeline. The limits of the pass / fail or go / no go tests became quite obvious. While the mandrel tests over the years clearly illustrated the continuous pipe deflection over time, the 2018 laser profile highlighted the extremes in deflection that demand vigilance. Many of the areas of most concern were beyond the failure points of the previous mandrel testing.

Table 2: Forty-two-year deflection summary

Vernon Heights Subdivision - Allen Co., Lima OH							
Street	**MH #s**	**Length (ft)**	**1976 5% Mandrel 7.50" OD**	**1982 5% Mandrel 7.50" OD**	**1989**		**2018 Laser Profiling MAX Deflection**
					6.5% Mandrel 7.38" OD	**8.5% Mandrel 7.22" OD**	
Elm	6-5	350	PASS	FAIL	FAIL	FAIL	11%
	5-4	320	PASS	FAIL	FAIL	FAIL	**19%**
Lowell	18-17	233	PASS	PASS	FAIL	PASS	10%
	17-16	258	PASS	FAIL	FAIL	FAIL	14%
	16-11	320	PASS	FAIL	FAIL	PASS	10%
	15-14	265	PASS	FAIL	FAIL	PASS	12%
	14-11	391	PASS	FAIL	FAIL	PASS	13%
Wendell	23-22	160	PASS	FAIL	FAIL	FAIL	13%
	22-21	246	PASS	FAIL	FAIL	FAIL	9%
	21-12	331	PASS	FAIL	FAIL	FAIL	11%
	20-19	162	PASS	FAIL	FAIL	FAIL	**17%**
	19-12	304	PASS	FAIL	FAIL	FAIL	13%
Lakewood	27-26	212	PASS	FAIL	FAIL	FAIL	**17%**
	26-13	287	PASS	FAIL	FAIL	FAIL	**32%**

The much more detailed report created by laser profiling enabled a full profile of the complete lines as seen in Figure 8. The previous inspections were limited to identifying the point in the line beyond which the 8.5% mandrel would not pass. It is possible that the most serious concerns weren't identified in previous testing because they were beyond the point of failure. The deflections documented in 2018 show continuing vertical deflection within the segments of pipe that were measured in 1989.

The laser profile identified two lines with 17% deflection, one line with 19% deflection and one line that surpassed 30% deflection.

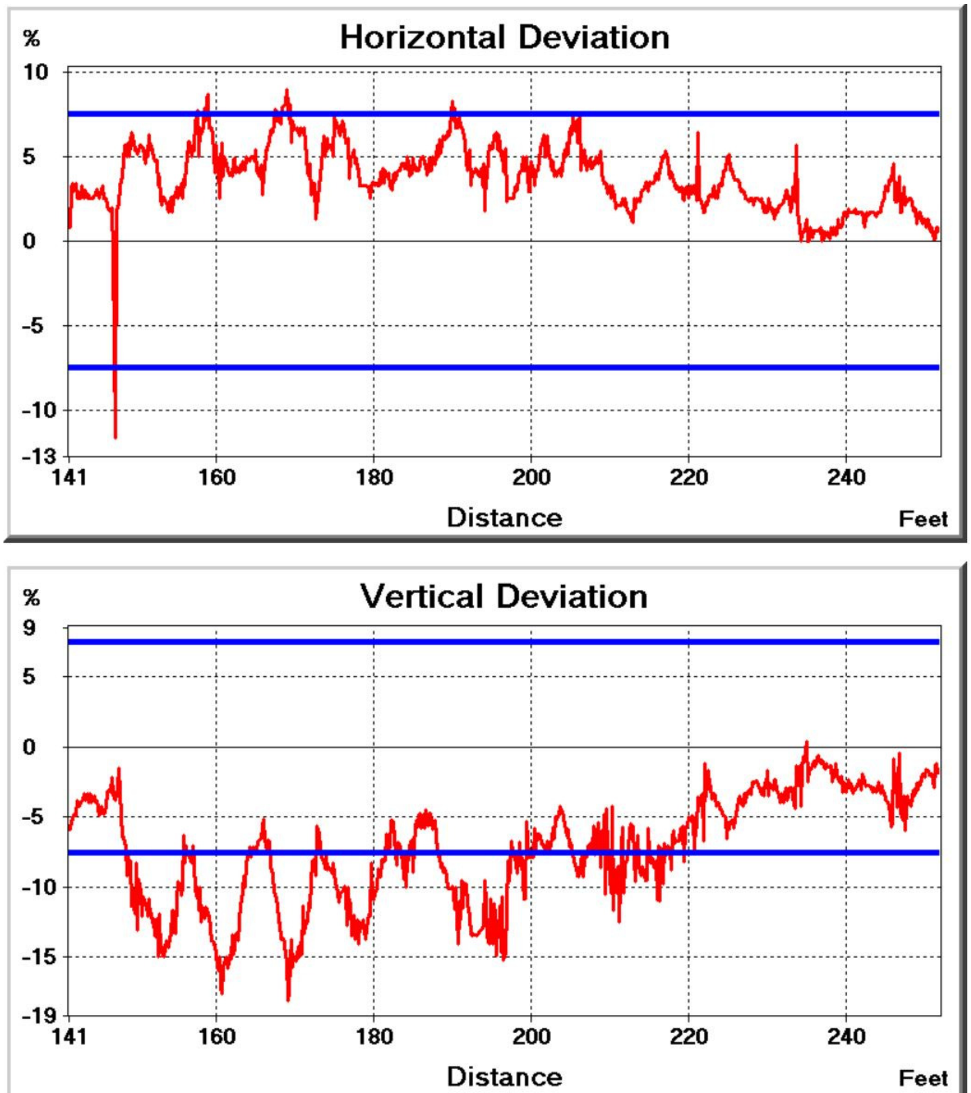


Figure 8: Sample of the Horizontal and Vertical line scan from the Lima study inspection run for 141 – 250 feet from manhole 17 to manhole 16.

ANALYSIS & CONCLUSIONS

All 14 lines are at or beyond the maximum allowable long-term vertical deflection of 7.5% as defined by the U.S. Department of the Interior, Bureau of Reclamation publication M-25: *Method for Prediction of Flexible Pipe Deflection, Second Edition* and ASTM D3034. The GREENBOOK and many other municipal standards are much more stringent than 7.5%. Eleven of the 14 lines are well-beyond the recommended limit and will likely need to be addressed short of the expected service life of 50-years.

In 1989, 70% of the lines installed in 1976 were beyond the maximum allowable deflection. By 2018 none of the lines were within the limit of 7.5%. Flexible pipe deflection is not occurring in a straight-line plot, but continues over time as found in this study.

Some of these lines could possibly make it to their projected 50-year service life, but with the continuing deflection over-time, reliance on continued performance would not be advisable. The variable dimensions of the pipe also present challenges related to cleaning and maintenance.

The pipelines in this trial have been prioritized for replacement.

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